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Mean Blood Lead Level in Iranian Workers: A Systematic and Meta-Analysis

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Abstract

Context: Exposure to lead is a global health issue. Several studies have demonstrated the harmful and irreparable effects of this heavy metal on human. Workers in lead-related industries are more exposed to lead than other people are. Therefore, the present study was conducted to assess the mean blood lead level (BLL) in Iranian workers through meta-analysis technique.

Evidence Acquisition: The present study was conducted based on PRISMA guidelines for systematic review and meta-analysis studies. We searched national and international online databases such as Magiran, SID, Medlib, Iranmedex, Scopus, Embase, Science Direct, PubMed, Web of Science, and Google Scholar search engine using Mesh keywords up to 2017. Heterogeneity among studies was check using Q test and I^2 index. Data pooled using random effects model.

Results: In 31 studies including 2767 Iranian workers, the mean BLL was estimated to be 43.1 μg/dl (95% CI [Confidence Interval]: 35.19 - 50.83). The lowest and highest BLL was estimated in the west of Iran (28.34 μg/dl [95%CI: 17.31-39.37]) and center of Iran (46.32 μg/dl [95% CI: 36.73-55.91]), respectively. Regarding job-specific BLL, the lowest and highest BLL was estimated in textile industry workers (12.33 μg/dl [95%CI: 0-26.76]) and lead-zinc mines workers (72.58 μg/dl [95%CI: 26.06 - 119.10]), respectively. Mean BLL based on province was studied and the lowest level was estimated in Isfahan province (29.79 μg/dl [95%CI: 0-73.31]) and the highest level was estimated in Markazi province (96.47 μg/dl [95%CI: 88.61-104.33]). The relationship between mean BLL in Iranian workers, year of study (P = 0.46) and mean work experience (P = 0.15) was not significant.

Conclusions: Due to high BLL in Iranian workers in lead-related industries, it is necessary to increase frequent screening and protective activities and perform scheduled clinical and paraclinical examinations in workers.

Keywords: Lead, Blood, Workers, Meta-Analysis, Biological Assessment, Iran

1. Context

Lead is a natural compound that is found in several forms including elemental, mineral, and organic (1). Lead is used in various modern industries such as automotive industry, military, production of anti-corrosives, lead salts as color stabilizer, battery production, and leaded gasoline. Workers in these industries are in direct exposure to lead (2).

Nowadays, exposure to lead is considered a public and occupational health issue in the world (3). Lead poisoning is an increasing concern, particularly in developing countries, as a result of rapid urbanization, leaded fuels, and industrial pollutions (2). Lead enters our body in either mineral or organic (tetraethyl lead or leaded gas/oil) forms. Lead in mineral compounds often enters the body through the lung and gastrointestinal tract, whereas lead in organic compounds is absorbed through the skin surface (4).

Lead is in no way useful in human body and any amount of this element is harmful to our body (3). Known complications of long-term exposure to lead include hypertension, toxicity of kidney nephrons, cardiovascular disorders, hemoglobin disorder, cognitive disorders, memory loss and malignity of stomach, lung, and bladder (5-7).

Determination of human risk factors regarding exposure to heavy metals is done using biological samples such as blood, blood plasma, urine, hair, nail, and saliva (8).

Lead poisoning is more common in workers that work in printing office, arms factory, gas station, paint factory, battery production factory, gasoline refinery, industrial wastewater treatment plants, tailpipe factory, lead alloys

smelting factory, and body shops (9-12). Numerous studies have been conducted in Iran regarding occupational and biological exposure of workers to lead and diverse statistics have been presented (9-31). Therefore, a structured review of all documents and combining them can give us a clear picture of various dimensions of this problem in Iranian workers and help us carry out preventive measures. Meta-analysis is a technique that gathers and analyzes various research with common goals to present a reliable estimate regarding the effectiveness of medical interventions or observations (32, 33). In the meta-analysis method, since data are collected from several studies, we have more samples and thus the range of possibilities and changes is more limited. As a result, the importance of statistical results increases (33, 34). Therefore, the present study was conducted to assess the mean blood lead level (BLL) in Iranian workers through meta-analysis technique.

2. Methods

2.1. Protocol

The present study was conducted based on PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines for systematic review and meta-analysis (34). To avoid bias, all procedures of the research were done by two researchers independently and the appraisal of agreement between results was done by a third researcher.

2.2. Search Strategy

We searched national and international Online databases such as Magiran, SID (Scientific Information Database), Medlib, Iranmedex, Scopus, Embase, Science Direct, Web of Science (ISI), PubMed, and Google Scholar search engine up to 2017. To maximize the comprehensiveness of the search, we used MeSH keywords with all possible combinations in English databases: "Occupational Exposure", "Occupational Diseases", "Environmental Exposure", "Metals, Heavy", "Lead", "Lead Poisoning" and "Iran". For national databases, an equivalent of Persian keywords was used. References of all relevant articles were reviewed.

2.3. Inclusion and Exclusion Criteria

The inclusion criteria included reference to BLL in Iranian workers (in Persian or in English). The exclusion criteria were: 1. Studies conducted outside Iran, 2. Samples containing non-exposed workers, 3. Non-random sample size, 4. Not relating to the topic, 5. Unavailability of epidemiologic information, and 6. Reviews studies, case reports, and editorials. In case of ambiguity or specific question, we contacted the authors by email.

2.4. Quality Assessment

Researchers assessed the quality of studies using STROBE checklist (35). This checklist includes 22 different parts to evaluate various aspects of the methodology including sampling method, measuring variables, statistical analysis, modification of confounding factors, specifying validity and reliability of tools, goals of the study and etc. The authors adopted a simple method of scoring. 0 to 2 score was given to each part of the checklist and the points given to each article by the two researchers were compared at the end. The minimum and maximum attainable scores in this checklist were 0 and 44, respectively. The minimum acceptable score was 16 and the articles that received minimum quality assessment score entered the meta-analysis process.

2.5. Study Selection

422 studies were identified in the asystematic review and after screening the titles, 222 studies were excluded due to being duplicated. Abstracts of 210 relevant studies were reviewed and 127 studies were excluded due to being irrelevant. After evaluating inclusion and exclusion criteria and assessing the quality of the 83 remaining studies, 31 studies were finally qualified to enter meta-analysis (Figure 1).

2.6. Data Extraction

All the included studies were prepared for data extraction by a pre-prepared checklist. The checklist included the name of the authors, location of the study, type of the study, sample size , province, work experience (Mean $\pm$ SD), age (Mean $\pm$ SD), job of workers, mean BLL (Mean $\pm$ SD) in workers.

2.7. Statistical Analysis

Normal distribution was used to calculate the standard error. To assess the heterogeneity of studies, Cochran's Q test and I^2 index were used. In this study, the heterogeneity was found to be 99.9%, which falls into the category of studies with high heterogeneity (if I^2 index is lower that 25%, the heterogeneity is low; if it is 25 - 75%, the heterogeneity is medium, and if it is higher than 75%, the heterogeneity is high). Due to the heterogeneity of studies and significance of I^2 index, random effects model was used in the meta-analysis. To find the source of heterogeneity, meta-regression model was used based on year of study and work experience and also subgroup analysis was used based on geographic region, province, and occupation. To determine the stability of the data, sensitivity analysis was performed. Begg's and Egger's funnel plot was used to assess publication bias. The data

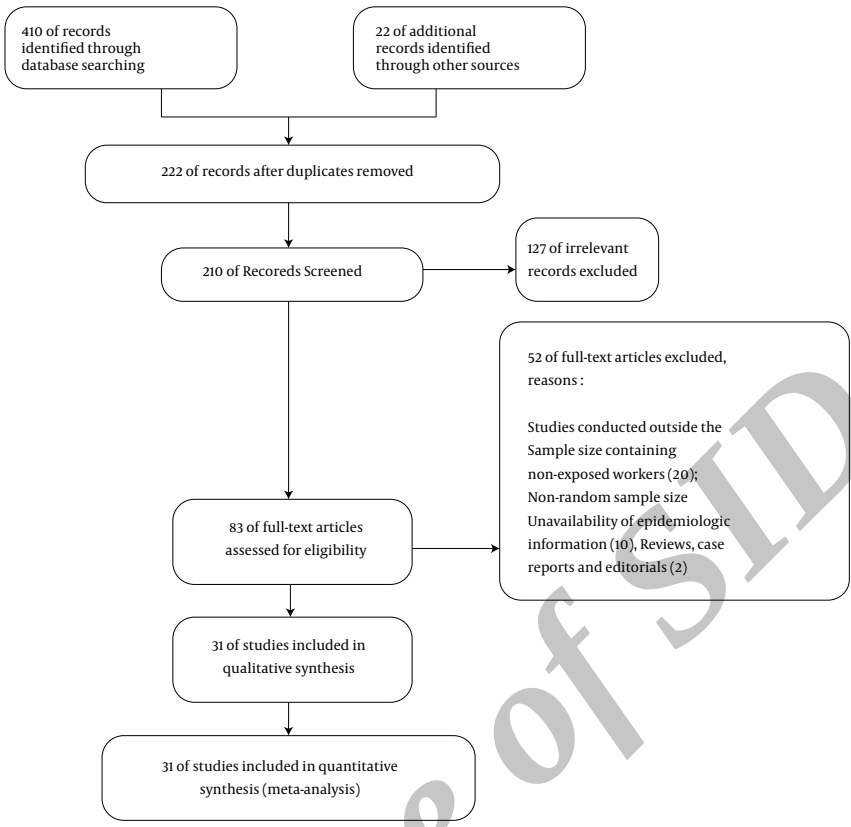

Figure 1. Diagram the Process of Selecting Studies for Systematic Review

were analyzed using Stata Ver.11.1 software and $P < 0.05$ was considered significant.

3. Results

3.1. Search Results and Study Characteristics

Overall, 31 qualified studies, conducted from 1994 to 2014, entered the process of meta-analysis (Figure 1). The sample size contained 2,767 workers. Table 1 presents the data and general specifications of each sample.

3.2. Mean BLL in Iranian Workers

Mean BLL in Iranian workers was estimated to be 43.1 μg/dl (95% CI [Confidence Interval]: 35.19-50.83). The lowest and highest BLL was observed in Tabrizizadeh study (2006) in Yazd (4.97 μg/dl) and Reihani Kermani study (2004) in Tehran (96.7 μg/dl), respectively (Figure 2).

3.3. Sensitivity Analysis

To assess the influence of each study, sensitivity analysis was conducted by sequential removal of each study, which indicated our results were reliable and conservative (Figure 3).

3.4. Mean BLL in Iranian Workers Based on Geographic Regions and Province

Region-based BLL level presented in Figure 4 shows that the lowest and highest BLL was estimated in the west of Iran (28.34 μg/dl [95% CI: 17.31-39.37]) and center of Iran (46.32 μg/dl [95% CI: 36.73-55.91]), respectively. Mean BLL based on province was studied and the lowest level was estimated in Isfahan province (29.79 μg/dl [95% CI: 0-73.31]) and the highest level was estimated in Markazi province (96.47 μg/dl [95% CI: 88.61-104.33]) (Table 2 and Figure 5).

3.5. Mean BLL in Iranian Workers Based on Job-Specific

Table 3 present job-specific mean BLL; the lowest and highest BLL was estimated in textile industry workers (12.33 μg/dl [95%CI: 0-26.76]) and lead-zinc mines workers (72.58 μg/dl [95%CI: 26.06 - 119.10]), respectively.

3.6. Meta-regression

Meta-regression model was used to study the relationship between mean BLL in Iranian workers and year of the study, which was not statistically significant (P = 0.469) (Figure 6A).

Meta-regression model was also used to study mean BLL based on mean work experience of workers and P-value was estimated to be 0.157 (Figure 6B).

3.7. Publication Bias

Funnel plot was used for publication bias in the studies entered the meta-analysis (Figure 7) and publication bias, Egger's and Begg's tests were estimated to be significant (P < 0.001).

4. Discussion

There is no accurate information regarding BLL in various groups of Iranian workers. However, it is necessary to have a general understanding of the present situation for planning, performing protective measures, and making proper policies in future (35, 36). In this study, occupational and biological exposure to lead in Iranian workers was assessed based on region, occupation, province, year of the study, and mean work experience. The overall mean BLL was estimated to be 43.1 μg/dl for all Iranian workers. This high level of lead in Iranian workers may be due to weak and inappropriate protective equipments or other factors such as nutrition, age, and duration of exposure. Lead level is not the same in different countries: Poland (154.8 μg/dl), Ethiopia (40 μg/dl), Pakistan (10 - 60 μg/dl), and Korea (4.35 μg/dl). This diversity may be due to the type of job, safely level, and development level of the country (37-40). Studies show that the situation is worse in developing countries (36).

According to Occupational Safety and Health Administration (OSHA), BLL lower than 9 μg/dl is normal, 10 - 42 μg/dl is acceptable for long-term exposure, and higher than 42 μg/dl is over the acceptable limit (41). This study shows that BLL in Iranian workers is slightly over the allowable limit (according to OSHA), which may lead to various complications such as malignity of stomach, lung, and bladder with mechanisms of free radicals generation (42).

In this study, the lowest and highest BLL was observed in the west (28.34 μg/dl) and center (46.32 μg/dl) of Iran, respectively. This diversity may be due to the type of factories in these regions. For instance, most battery production factories and lead-zinc mines are located in the center of Iran. Mean BLL based on each city was also studied and the highest level was found in Markazi (96.4 μg/dl) and Razavi Khorasan (72.2 μg/dl), which may be due to the existence of lead mines in these regions, misuse of protective equipments, or not using protective equipment at all.

Regarding job-specific mean BLL, lead-zinc mine workers and welders have the the highest BLL. Therefore, the possibility of lead poisoning is high in these occupations and it is necessary to screen BLL of lead-zinc mine workers and welders to prevent hematic, cardiac, renal, neurologic, malignant, and other complications and they need to be treated if necessary. Studies show that BLL in foundry workers is higher than in others; this may be due to high temperature (500 - 600°C) in such environments that leads to evaporation and release of lead in the air and its entrance into blood through lungs (31). Direct contact with lead, ignoring safety and health lead-related rules, not bathing and lack of proper ventilation in the workplace are some of the causes of the high level of lead in these workers.

In the present study, the lowest mean BLL was observed in textile industry workers (12.3 μg/dl); obviously due to the lack of direct contact with lead. After textile industry workers, gas station workers (30 μg/dl) had the lowest mean blood lead level. That is because the number of studies dedicated to mean BLL of gas station workers is limited and more studies should be conducted on this issue.

Studies to determine hair lead level in Iranian workers are very rare and one of the reasons is an undefined threshold of health for hair lead in chronic exposure. Thus, due to noninvasiveness and cost-effectiveness of this method, it is necessary to carry out a nationwide study to determine the threshold of health for hair lead level in Iranian workers.

Studies of Hu and Schwartz demonstrated that genetic factors can influence toxic effects of lead on body, which include metabolism and excretion of lead. As a result, worker's vulnerability to lead poisoning affects the subsequent disorders and complications. Therefore, lead level that is harmful to a person may not be harmful to another person (43). Thus, considering the toxic effects of lead, which may occur at subclinical level, and considering that treatment of workers with high level of lead can be difficult, it is necessary to take into consideration the exposure to heavy metals such as lead seriously and not to neglect the controlling measures.

Meta-regression model was used to study the relationship between mean BLL in Iranian workers and year of the study, which was not statistically significant, and mean BLL during the years of study (1994 - 2014) was almost stable. Stability of this high BLL in Iranian workers in the last 20 years indicates negligence of authorities regarding problems of Iranian workers and it is necessary to screen these workers to detect disorders and complications of high blood lead level.

Meta-regression model was also used to study the re-

Table 1. Summary of Literature

Ref	Author Name, Year of publication	Place	Year	Sample Size	Occupation of Workers	Average Work Experience, Mean ± SD	Average Age, Mean ± SD)	Mean Blood Lead Level, μg/dl
(9)	Shahrabi Farahani J, 2006	Tehran	2006	12	Welder	8.90 ± 5.99	33.20 ± 7.40	62.60 ± 13.40
(9)	Shahrabi Farahani J, 2006	Tehran	2006	12	Welder	5.70 ± 4.77	30.50 ± 5.23	67.20 ± 12.80
(10)	Reihani Kermani H, 2005	Tehran	2004	50	Battery industry	9.90 ± 6	30.50 ± 5.80	96.70 ± 27.90
(11)	Dehghan Nasiri M, 2012	Tehran	2011	60	Automobile industry	10 ± 5	33.60 ± 5.20	36.30 ± 9.90
(12)	Sadeghniat haghighi Kh, 2013	Tehran	2007	113	Battery industry	15.92 ± 6.95	40.88 ± 7.07	41.40 ± 16.90
(13)	Fazli D, 2014	Tehran	2014	35	Car repairs	10.60 ± 5.35	31.37 ± 3.79	38 ± 10.70
(14)	Aliasgharpour M, 2004	Tehran	2002	35	printing industry	12 ± 8	35 ± 9	13.63 ± 3.20
(14)	Aliasgharpour M, 2004	Tehran	2002	25	Battery industry	12 ± 6	35 ± 7	37.98 ± 5.10
(15)	Nazifi Habib Abadi S, 2014	Tehran	2002	60	Painter			27.76 ± 3
(16)	Ghiasvand M, 2013	Tehran	2011	497	Battery industry	12.90 ± 70	41.70 ± 6.50	43.30 ± 17.90
(17)	Abdollahi M, 1996	Tehran	1994	20	Printing industry			75 ± 23
(18)	Abdollahi M, 1996	Tehran	1994	20	Print industry			50.71 ± 2.60
(19)	Sadeghi M, 2014	Esfahan	2012	142	Battery industry	23.54 ± 14.40	41.78 ± 13.50	7.59 ± 2.75
(20)	Malekirad AA, 2013	Esfahan	2011	316	Battery industry	8.93 ± 5.76	33.41 ± 6.88	52 ± 8
(21)	Tabrizi Zadeh M, 2006	Yazd	2006	70	Textile industry	16.10 ± 6.95	37.70 ± 8.03	4.97 ± 1.70
(21)	Tabrizi Zadeh M, 2006	Yazd	2006	70	Battery industry	15.60 ± 6.65	38.80 ± 8.03	7.06 ± 4.84
(22)	Ghoreishian SM, 2004	Yazd	2004	15	print industry			36.14 ± 6.80
(22)	Ghoreishian SM, 2004	Yazd	2004	21	Battery industry			46.77 ± 3
(22)	Ghoreishian SM, 2004	Yazd	2004	12	Painter			47.84 ± 3
(22)	Ghoreishian SM, 2004	Yazd	2004	12	Welder			59.42 ± 3
(23)	Aminipour M, 2008	Yazd	2008	490	Lead-zinc mines			49 ± 23.40
(24)	Yartireh H, 2013	Kermanshah	2001	70	Textile industry			19.70 ± 3.90
(24)	Yartireh H, 2013	Kermanshah	2001	150	Oil refinery			53.30 ± 6.68
(25)	Karimooy NH, 2010	Mashhad	2010	108	Traditional tile factories	9.80 ± 6	37 ± 7.80	36.10 ± 17.60
(26)	Kianoush S, 2003	Mashhad	2011	112	Battery industry	3.89 ± 2.40	27.78 ± 5.17	39.90 ± 17.70
(27)	Keramati MR, 2010	Mashhad	2006	89	Battery industry	2.90 ± 1.60	30 ± 5	32.20 ± 13.70
(28)	Kalantari S, 2009	Zanjan	2009	40	Lead-zinc mines		31.10 ± 5.80	16.06
(29)	Bahrami AR, 2002	Hamedan	2002	44	Gasoline-Station	13.52 ± 6.82	39.38 ± 8.03	30.05 ± 71
(30)	Malekirad AA, 2010	Arak	2008	67	Lead-zinc mines	14.70 ± 8.20	39.70 ± 8.20	96.40 ± 32.80

lationship between mean BLL and mean work experience of workers and the relationship was not statistically significant. Most studies demonstrated that there is a direct relationship between mean BLL, mean work experience of

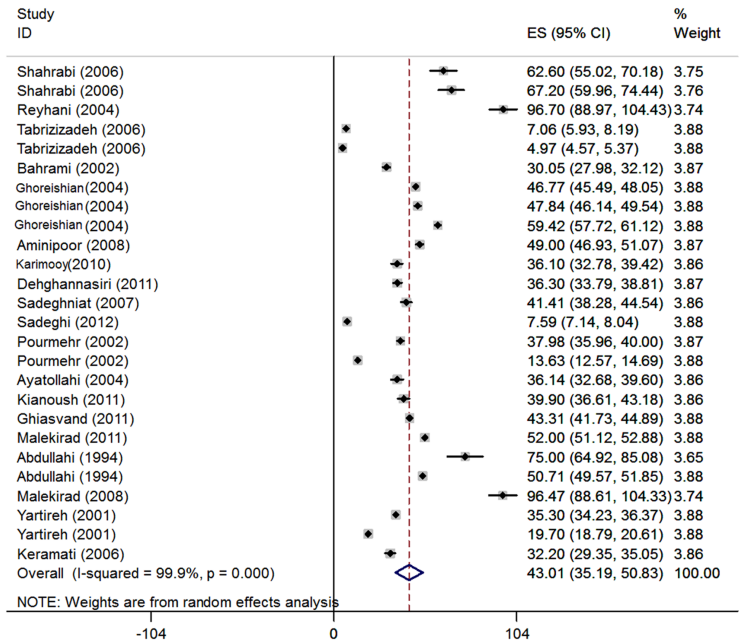

Figure 2. Forest Plots of Mean BLL in Iranian Workers. Random effects Model.

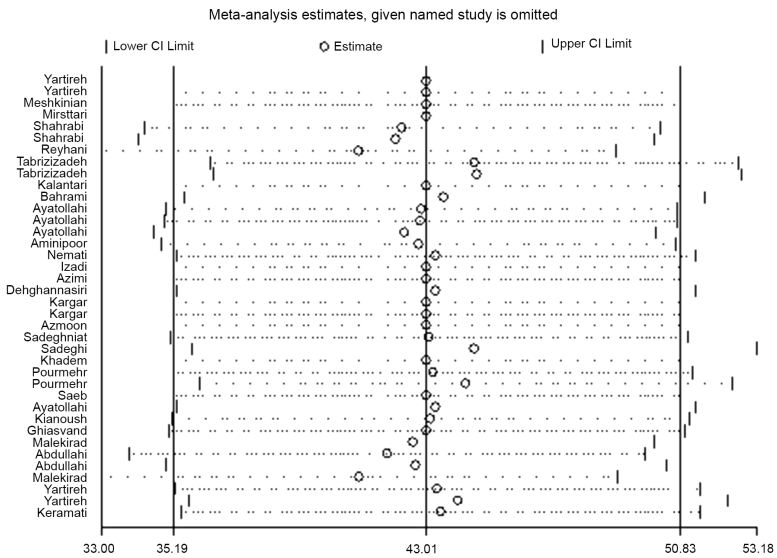

Figure 3. Forest Plots of Sensitivity Analysis for Mean BLL in Iranian Workers

workers, and mean age of workers; that is, as workers become older and get more experienced, lead level increases in their blood (39, 40). Lack of a significant relationship in our study may be due to the minimal difference between mean work experience and the mean age of workers who participated in these studies.

4.1. Week and Strong Points of the Study

Presentation of BLL concentration in workers with different conditions of lead exposure was noticable as a weak-

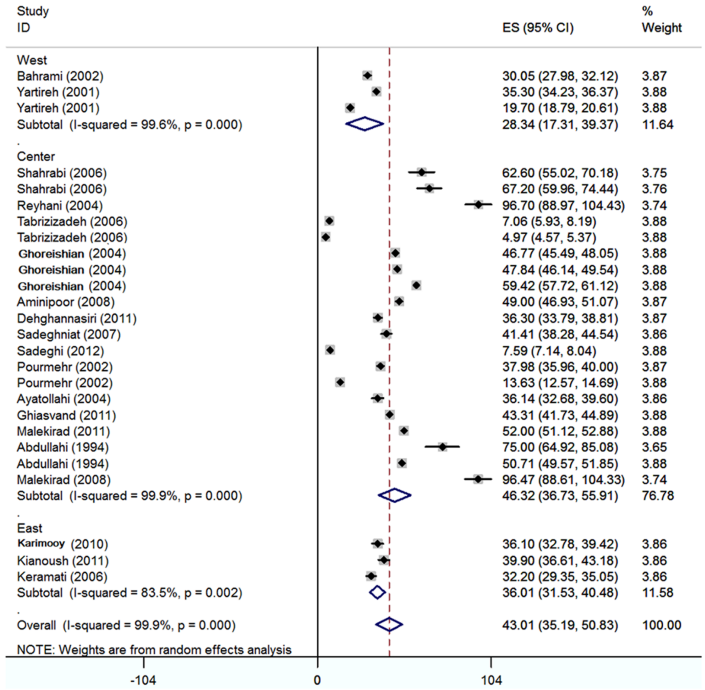

Figure 4. Forest Plots of Mean BLL in Iranian Workers Sub-grouped by Regions. Random Effects Model.

Table 2. Mean BLL Subgrouped by Province in Iranian Workers

Province	Studies (N[a])	Sample Size (N[a])	I^2	95% CI[b]	Mean BLL
Tehran	11	939	99.9	39.56 - 61.97	50.77
Yazd	7	675	99.6	16.80 - 54.96	35.88
Isfahan	2	458	100	0 - 73.31	29.79
Kermanshah	2	220	99.8	12.21 - 42.79	27.50
Hamedan	1	44	0	27.98 - 32.12	30.05
Markazi	1	67	0	88.61 – 104.33	96.47
Razavi Khorasan	3	301	83.5	31.53 – 40.48	36.01

[a]Number
[b]Confidence interval

ness of this study.

Accurate estimation of mean BLL concentration may indicate occupational exposure to lead in Iranian workers and evaluation of BLL in Iranian workers by occupation, year of study, job experience, geographic region, and province can be the novelties and strengths of this study.

4.2. Limitations

1. Inability of internal databases to combine search keywords; 2. Lack of a specific framework in reported units for mean lead level; 3. Scarcity of gender-specific studies of mean blood lead level leading us to not being able to present statistics on this issue; 4. Lack of studying job-specific mean BLL in some regions due to the lack of primary studies, and 5. Diversity of maximum allowable level of lead in different studies, leading us to not being able to present statistics regarding the number of workers with lead over the acceptable limit.

4.3. Conclusion

Considering the high BLL in workers, it is necessary to increase frequent screening and protective activities, use

Table 3. Mean BLL Subgrouped by Job in Iranian Workers

Job	Studies (N[a])	Sample Size (N[a])	I^2	95% CI[b]	Mean BLL
Welder	3	36	54.7	57.31 - 66.78	62.05
Battery industry	10	1450	99.9	25.42 - 55.28	40.35
Textile Industry	2	140	99.9	0 - 26.76	12.33
Lead - zinc mines	2	220	99.2	26.06 - 119.10	72.58
Gasoline - Station	1	104	0	27.98 - 32.12	30.05
Oil refinery	1	300	0	34.23 - 36.37	35.30
Traditional ceramics industry	1	108	0	32.78 - 39.42	36.10
Printing industry	3	70	99.3	17.34 - 64.55	40.94
Car repair	1	35	50.4	34.46 - 41.54	38

[a]Number
[b]Confidence interval

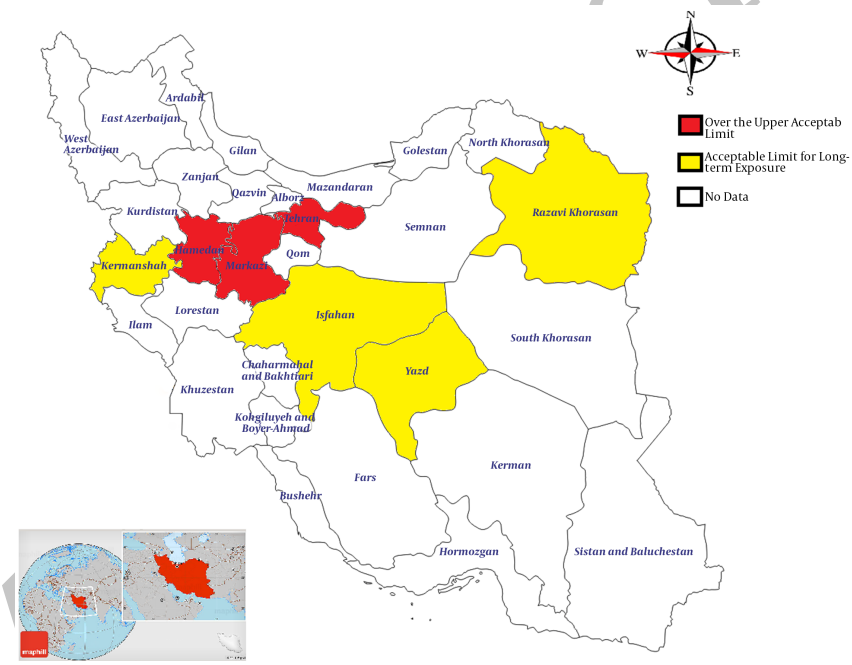

Figure 5. The Geographical Distribution of Blood Lead Levels in Iranian Workers According to Occupational Safety and Health Administration, Blood Lead Levels Lower Than 9 μg/dl is Normal, 10 - 42 μg/dl Is Acceptable for Long-Term Exposure and Higher Than 42 μg/dl Is Over the Upper Acceptable Limit

more powerful ventilations, use mask and proper outfit, and perform scheduled clinical and paraclinical examinations for workers in addition to monitoring workers' skin and breathing openings in exposure to lead. To improve the personal safety of workers, it is necessary to have simple training plans to prevent lead poisoning. These plans may include an introduction, a simple diet and regular use of milk, improving workers' information about lead poisoning, wearing masks, changing work clothes regularly, bathing after work, washing hands before leaving the workplace, and informing workers about long-term complications of lead poisoning even after treatment.

Considering the effect of genetic factors on lead poisoning in different people according to the studies from other countries, it is necessary to carry out similar research in Iran and in case of positive results, workers who are more sensitive to lead poisoning should not be employed in lead-related industries.

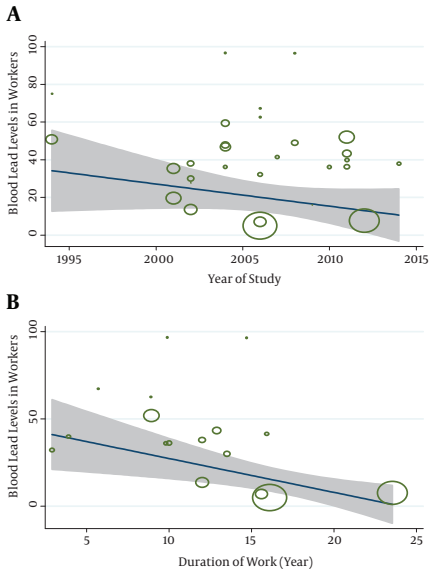

Figure 6. Mean BLL in Iranian Workers Based on Year of the Study (P = 0.469) (A) and Mean Work Experience (P = 0.157) (B)

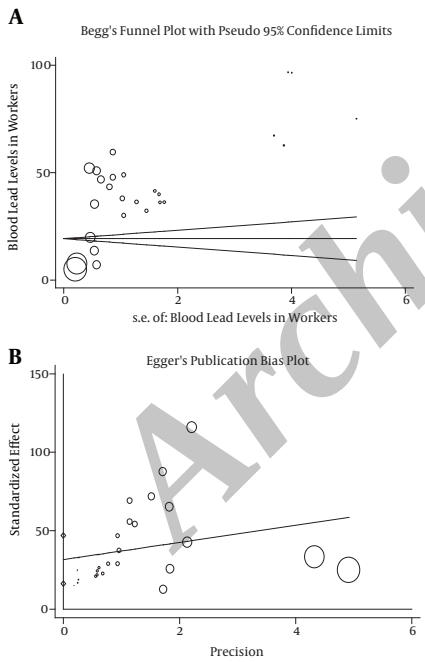

Figure 7. Publication Bias in the Studies Reviewed, Begg's (A) and Egge's (B)

Considering that a significant amount of lead is stored in bones and survives for several years and decades, the best way to determine body lead level is measuring the lead level in hard tissues such as tooth. Thus, a nationwide study to determine lead level in hard tissues of Iranian workers is advised.

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Footnotes

Authors' Contribution: All authors Data Collection and Study design and Quality evaluation and Final revision and Grammar editing; Kourosh Keshmiri Statistical analysis.

Conflict of interest: None in this article.

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